BMM87 BEARING LOAD ON A BRASS PIN WITH ALUMINIUM PLATES

MOHD NUR HILMI BIN MOHD NAZIH

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2012

ABSTRACT

The investigation is about the bearing load on a brass pin joined with Aluminium thin plates of variables thickness. The experiment had done using various dimensions of the specimens which is pin diameter, plates thickness and plate thickness to diameter ratio, t/D. The specimens were tested using universal tensile testing machine. The movement for upper crosshead of the testing machine is stopped when the specimen is break. For each specimen, the bearing load was taken and determined from the load vs. displacement graph which is obtained from the Trapezium software in computer that connects with the universal tensile testing machine. The differences dimensions of the specimens give different value of bearing load. By t/D ratio increasing, the higher load pin can support. The higher bearing load is obtained from 5mm brass pin diameter which is 3898.84 N. The finite element analysis ALGOR is use to compare the bearing stress value with experimental test, to choose the more accurate method for other investigation. Finally, the graph of bearing load vs. pin diameter can be used to design brass rivet in the future.

ABSTRAK

Kajian adalah mengenai beban galas yang dikenakan keatas pin tembaga yang bergabung dengan plat Aluminium yang nipis yang berlainan ketebalan. Eksperimen ini dijalankan menggunakan model yang berlainan saiz iaitu diameter pin, ketebalan plat dan nisbah ketebalan plat kepada diameter pin, t/D. Spesimen diuji dengan menggunakan mesin ujian tegangan universal. Gerakan untuk kepala pemegang bahagian atas mesin uji akan berhenti apabila specimen telah gagal atau pin tercabut daripada plat. Untuk setiap specimen, nilai beban yang menyebabkan kegagalan diambil dan ditentukan daripada graf beban melawan sesaran yang diperolehi dari perisian Trapezium dalam computer yang disambung pada mesin ujian tegangan universal. Perbezaan dimensi pada setiap spesimen memberikan nilai yang berbeza untuk beban kegagalan. Dengan nisbah t/D yang meningkat, lebih besar beban yang dapat ditanggung oleh pin. Beban galas paling tinggi diperolehi pada 5mm diameter pin tembaga ialah 3898.84 N. Analisis unsur terhingga oleh ALGOR digunakan untuk membandingkan nilai tegasan galas dengan ujikaji eksperimen, untuk memilih kaedah yang lebih tepat untuk kajian lain. Akhir sekali, graf untuk beban galas melawan diameter pin boleh digunakan untuk merekabentuk rivet tembaga pada masa hadapan.

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LIST OF SYMBOLS

L	Length of the plate, mm
P	Load by Universal Testing Machine, N
E	Distance between centre of hole and edge of the plate, mm
W	Width of the plate, mm
D	Diameter of the pin, mm
t	Thickness of the plate, mm
W/D	Width to Diameter ratio
E/D	Edge to Diameter ratio
t/D	Thickness to Diameter ratio
σ_b	Bearing stress, N/mm^2
τ	Shear stress, N/mm^2

LIST OF ABBREVIATIONS

FEA	: Finite Element Analysis
Al	: Aluminum
Br	: Brass
UTS	: Ultimate Tensile Strength

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Joints are primary sources of weakness in a structure. The mechanically connected structures using fasteners and bolted or pinned joints are a common occurrence in most engineering designs. Design procedures for pins joints have been developed and generally lead to successful applications and safe structures. The pin joint usually use in the applications where light weight and high strength are critical such as the joining structures of aircraft and aerospace vehicles. But, this type of joining have a possibility of serious failure can occur such as bearing stress and crack due to stress concentration and very danger to human. This can be avoided within it is properly designed and assembled by a trained mechanic. In practical structural connections, failure which may occur as a result of this interaction manifests itself as either pin shear, plate net-tension, plate shear-out tension or pin bearing against the plate in the direction of loading.

Bearing mode of failure occurred is due to the bearing stress. Bearing stress is caused by one component acting directly on another. The bearing stress is computed by dividing the load applied to the pin, which bears against the edge of the hole, by the bearing area. This failure can be investigated by apply load to the single shear plate joined by pin under tensile loading. Thus, the pin will be share the load in shear, bearing in the pin and the member, and shear in the pin. Pin joints are unavoidable in complex structures because of their low cost, simplicity, and facilitation of disassembly for repair. It is important therefore to determine the bearing load that pin can withstand in the connections and failure mode occurred.

In this project, we want to investigate the bearing load on a brass pin with Aluminium thin plates of variable thickness. The designing two flat Aluminium plate join by using brass pin, possibly failure might occur on the joints caused by bearing stress. This investigation used at least three set of the same thickness of Aluminium plates and three set of different thickness of Aluminium plates. Brass pin is been machined to many sizes to act as pins. Tensile machine is used to test the specimens and FEA software is used to speed up the investigation. Thus, the analysis from graph of bearing load versus diameter of pins could be used for future designed of rivet.

1.2 PROBLEM STATEMENT

In this project, we want to investigate the bearing load on a brass pin with thin Aluminium plates of variable thickness. The brass pins will act as a connector for two slide Aluminium plates. If bearing failure occurs, it will less cause in harm or disaster, as example in aerospace vehicles or construction. So, the right choice of pin diameter size is important, for it not to break off before its reach its maximum load.

1.3 PROJECT OBJECTIVES

i) To investigate the bearing load for different diameters of brass pin joined with Aluminium thin plates of variable thickness.

1.4 SCOPES

1) Using Aluminium plates thickness of 1mm, 2mm and 3mm.

2) Brass pin diameter of 3mm, 4mm and 5mm.

3) Investigation was limited to the size of the jaw of the Universal Tensile Testing Machine.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The main disadvantage of pin joints is the formation of high stress concentration zones at the locations of pin holes, which might lead to a premature failure of the joint due to net-section, shear-out, or bearing failures, or their combinations. In common case, design of pin connections can be realized according to standard design rules which is the pin and the plate thickness are designed according to their geometrical dimensions, geometry or dimensions of the plate is designed on the basis of its thickness. Some difficulties may occur in case of minimization of dimensions of connection plates or in the case of load carrying capacity determination of an existing pin connection. Scientists and engineers had been carefully analyzed the failed component to determine the cause of failure in most cases. The information gained is used to advance safe performance and minimize the possibility of failure through improvements in design, materials synthesis and selection.

2.2 STRENGTH OF MATERIALS

The strength of a material refers to the ability of a structure to resist loads without failure because of excessive stress or deformation. The applied stress may be tensile, compressive, or shear. Strength of materials is a subject which deals with loads, deformations and the forces acting on a material. A load applied to a mechanical member will induce internal forces within the member called stresses. The stresses acting on the material cause deformation of the material. Deformation of the material is called strain, while the intensity of the internal forces is called stress. The strength of any material relies on three different types of analytical method which is strength, stiffness and stability, where strength refers to the load carrying capacity, stiffness refers to the deformation or elongation and stability refers to the ability to maintain its initial configuration. Strength can be expressed in terms of compressive strength, tensile strength and shear strength. The ultimate strength refers to the point on the engineering stress-strain curve corresponding to the stress that produces fracture. Typical points of interest when testing a material including the ultimate tensile strength (UTS), offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation and the rupture (R) or fracture point where the specimen separates into pieces.

2.2.1 Ultimate Strength

Ultimate strength or tensile strength is a shortened word from ultimate tensile strength. It is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section starts to significantly contract. The value can be found by drawing a horizontal line from the maximum point on the stress-strain curve to the stress axis. The stress where this line intersects the stress axis is called ultimate tensile strength. If the specimen develops a localized decrease in cross sectional area, the engineering stress will decrease with further strain until fracture occurs since the engineering stress is determined by using the original cross sectional area of the specimen. The more ductile a metal is, the more the specimen will neck before fracture and hence the more decrease in the stress on the stress-strain curve beyond the maximum stress. The ultimate strength is not used much in engineering design for ductile alloys since too much plastic deformation takes place before it is reached. It is an intensive property, therefore its value does not depend on the size of the test specimen, it is dependent on other factors, such as the preparation of the specimen, the presence or otherwise of surface defects, and the temperature of the test environment and material (William et al., 2009).

2.2.2 Offset Yield Strength (OYS)

The yield strength or yield point of a material is defined in engineering and materials science as the stress at which a material begins to deform plastically. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible. Because there is no definite point on the stress-strain curve where elastic strain ends and plastic strain begins, the yield strength is chosen to be that strength when a definite amount of plastic strain has occurred. For American engineering structural design, the yield strength is chosen when 0.2 percent plastic strain has taken place. The 0.2 percent yield strength, also called the 0.2 percent offset yield strength, is determined from the engineering stress-strain diagram. It is the stress that corresponds to the point of intersection of a stress-strain diagram and a line parallel to the straight line portion of the diagram. Offset refers to the distance between the origin of the stress-strain diagram, and the point of intersection of the parallel line and the zero stress axes. Offset yield strength is arbitrary approximation of elastic limit. Knowledge of the yield point is vital when designing a component since it generally represents an upper limit to the load that can be applied.

2.2.3 Bearing Strength

Bearing strength is defined as the point where a bearing load does not cause plastic deformation. Most commonly this term is used in the analysis of bolts or pins where said members are placed in shear, thus resulting in the pin or bolt exerting a force or pressure against one side of the hole it passes through. In plastic industry, it is use to denote the ability of sheets to sustain edgewise loads that are applied by pins, rods or rivets used to assemble the sheets to other articles. Analyzing bearing strength, it is the load divided by the area it is acting against. For a pin or bolt, that area is the bolt shank diameter times the thickness of the material (Yi et al., 2005).

2.2.4 Shear Strength

Shear strength in engineering is a term used to describe the strength of a material or component against the type of yield or structural failure where the material or component fails in shear. A shear load is a force that tends to produce a sliding failure on a material along a plane that is parallel to the direction of the force. In structural and mechanical engineering the shear strength of a component is important for designing the dimensions and materials to be used for the manufacture or construction of the component.

2.2.5 Stress-Strain Relations

During tensile testing of a material sample, the stress–strain curve is a graphical representation of the relationship between stress, derived from measuring the load applied on the sample, and strain, derived from measuring the deformation of the sample. The slope of a stress-strain curve is known as Young's Modulus, or the Modulus of Elasticity. The Modulus of Elasticity can be used to determine the stress-strain relationship in the linear-elastic portion of the stress-strain curve. Elasticity is the ability of a material to return to its previous shape after stress is released. In many materials, the relation between applied stresses is directly proportional to the resulting strain, and a graph representing those two quantities is a straight line. Plasticity or plastic deformation is the opposite of elastic deformation and is defined as unrecoverable strain. Plastic deformation is retained after the release of the applied stress.

2.3 MECHANICAL FAILURE

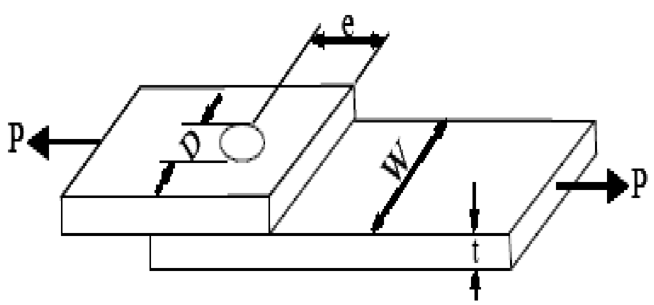
Mechanical failure might be defined as any change in the size, shape or material properties of a structure, machine or machine part that renders it incapable of satisfactorily performing its intended function. The three key for classifications of mechanical failure are the mechanisms, cause, and mode. These keys give the engineer a key view in understanding how and why a part failed and what can be done to prevent a failure in the future. Engineers are deeply aware of the possibility of fracture in load-bearing components and its potentially detrimental effect on productivity, safety and other economic issues. As a result all design, manufacturing and materials engineers use safety factors in their initial analysis to reduce the possibility of fracture by essentially overdesigning the component or the machine. It is imperative to understand that mechanical parts, like most other items, do not survive indefinitely without maintenance (William et al., 2009).

2.3.1 Ultimate Failure

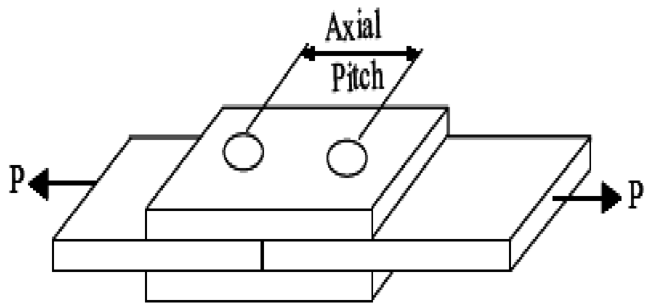
In mechanical engineering, ultimate failure describes the breaking of a material. In general there are two types of failure which are fracture and buckling. Buckling occurs when compressive loads are applied to the material and instead of cracking the material bows. This is undesirable because most tools that are designed to be straight will be inadequate if curved. If the buckling continues, it will create tension on the outer side of the bend and compression on the inner side, potentially fracturing the material. Fracture of a material occurs when either an internal or external crack elongates the width or length of the material. In ultimate failure this will result in one or more breaks in the material. There are two different types of fracture which are brittle and ductile. Each of these types of failure occurs based on the material's ductility. Brittle failure occurs with little to no plastic deformation before fracture. While applying a tensile stress to a ductile material, instead of immediately breaking the material will instead elongate. The material will begin by elongating uniformly until it reaches the yield point, then the material will begin to neck. When necking occurs the material will begin to stretch more in the middle and the radius will decrease. Once this begins the material has entered a stage called plastic deformation. Once the material has reached its ultimate tensile strength it will elongate more easily until it reaches ultimate failure and breaks.

2.4 MECHANICALLY FASTENED JOINTS

Mechanical joints are used when repeated disassembly and reassembly is required or when surface preparation is not practical. Mechanical joints can be readily inspected before assembly and while in service. Examples of two typical joints are the single lap joint and double lap joints as shown in **Figure 2.1**. The single lap joint is the simplest and most weight efficient but the load results in a moment due to off-set load. The double lap joint will eliminate the moment but adds additional weight from the straps and additional fastener. Mechanical fasteners are used in assemblies for their strength, reusability and appearance. A fastener is defined as an act of bringing together, connecting or uniting to becoming one or a unit. It also can be classified a hardware device that mechanically joins or affixes two or more objects together. It will hold the part of a structure together by transferring load from one component to another. There are many types of fasteners widely use, for example, bolts, rivets, nails, screws and pins.



(a)



(b)

Figure 2.1: Basic types of mechanical joints. (a) Single lap joint, (b) double lap joint

2.4.1 Pins

Pin can divide into two categories which is fasteners and fixture pins. Pin joints represent either 3D double shear or 2D single shear joints that are applied in many engineering structures from the skeletal frameworks to the outer skin of aircraft, automobiles, buildings and pressure vessels. The stresses and slips in the vicinity of contact regions determine the static strength, plasticity, frictional damping and vibration levels, and affect the structural performance. Stress will occur on fasteners due to the load applied. Two important types of stress in fasteners are bearing stress and shear stress.

2.4.1.1 Bearing Stress

Bearing stress is caused by one component acting directly on another or the contact pressure between the separate bodies. It is corresponding to average force intensity. It can be calculated by dividing the bearing force to the projected area of the fasteners. For cylindrical fasteners, the projected area is a rectangle. It differs from compressive stress, as it is an internal stress caused by compressive forces.

$$\sigma_b = \frac{F}{Dt} \tag{2.1}$$

2.4.1.2 Shear Stress

Shear stress is the result of two opposite transverse forces being applied on either side of a plane of a component. It is arises from the force vector component parallel to the cross section. For shear strength, it is the material's ability to endure the applied stress. If enough stress is applied to a body it may not return to its original shape. For a component under single shear, the average shear stress (τ) is the applied load (P) divided by the cross-sectional area (A) of the component, or $\tau = P/A$. For fastener, the average shear stress, (τ), is the shear force transferred divided by the cross-sectional area, which is generally a circle.

$$\tau = \frac{P}{\pi D^2/4} \tag{2.2}$$

2.4.2 Mechanical Fastened Joint Failure Mode

It has been observed experimentally that mechanical fastened joints fail under three basic mechanisms which are net-tension, shear-out and bearing. Typical damage caused by each mechanism is shown in **Figure 2.2**. Net-tension failure or normal failure involves a fracture across the width of the joint and normally occurs when the width distance to diameter ratio (W/D) is small. For shear-out failure, it is occurs when a plug of material separates from the laminate ahead of the pin and normally occurs when the edge distance to diameter ratio (E/D) is small. Shear-out failure can therefore occur after some bearing damage has initiated. If bearing failure occurs, it will less cause in harm or disaster. Bearing failure is defined as local crushing of the material adjacent to the hole and normally occurs when E/D and W/D ratios are large (Taner et al., 2007).

(a) (b) (c)

Figure 2.2: Types of damage failure mode samples after pin loading experiments.
(a) net-tension failure type, (b) shear-out failure type, (c) Bearing failure type.

- Source: Taner et al. (2007)

2.5 MATERIALS

2.5.1 Aluminum

Aluminum is an abundant metallic chemical element which is widely used and the third most common element in the Earth's crust and it is the most common metallic element on Earth. Pure Aluminium (99%) is soft, ductile, corrosion resistant and has a high electrical conductivity. It is one of the lightest engineering metals, having a high strength to weight ratio superior to steel. Aluminium is well suited to cold environments because its' tensile strength increases with decreasing temperature while retaining its toughness. It has excellent resistance to most acids but less resistant to alkalis. It cause by the Aluminium oxide layer form instantaneously when exposed to air. Aluminium can be severely deformed without failure. This allows Aluminium to be formed by rolling, extruding, drawing, machining and other mechanical processes. The ultimate tensile strength of Aluminum 1050-H14 use in this investigation is 110Mpa and yield tensile strength is 103Mpa. Aluminium is most commonly alloyed with copper, zinc, magnesium, silicon, manganese and lithium. These alloys are used in construction, airplane and automobile structures, traffic signs, heat dissipative, storage deposits, bridges and kitchen utensils. It also uses in chemical process plant equipment, food industry containers, pyrotechnic powder, architectural flashings, lamp reflectors and cable sheathing.

2.5.2 Brass

Brass is an alloy of copper and zinc. Typically it is more than 50% copper and from 5 to 20% zinc, in comparison to bronze which is principally an alloy of copper and tin. It is usually use for applications where low friction is required such as locks, gears, and bearings. Brass has higher malleability than bronze or zinc. Combinations of iron, aluminum, silicon and manganese make brass stronger and corrosion resistant. It resists corrosion especially seawater corrosion and metal fatigue better than steel and also conducts heat and electricity better than most steels. It is susceptible to stress cracking when exposed to ammonia. These investigations use the red brass having relatively low melting point of 990 to 1025°C. This brass contains 85% of copper and 15% of zinc. By varying the proportions of copper and zinc, the properties of the brass can be changed, allowing hard and soft brasses. The density of the brass is 8750 kg/m^3 which